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Emmerink, R.H.M.; Nijkamp, P.; Rietveld, P.

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Is congestion pricing a first-best strategy in transport policy? A critical review of arguments

R H M Emmerink[¶], P Nijkamp, P Rietveld

Department of Spatial Economics, Free University, De Boelelaan 1105, 1081 HV, Amsterdam, The Netherlands

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Abstract. In this paper, the arguments used in the literature pro and contra congestion pricing are analysed. Although it is a first-best instrument in theory, it is argued that the assumptions needed to arrive at this conclusion oversimplify reality. In practice, congestion pricing is a second-best instrument with some advantages over other second-best instruments, but it will also give rise to numerous problems, as discussed in the paper. These problems will be illustrated with the Dutch attempts to implement an electronic road-pricing system.

Some research issues relating to congestion pricing have been overlooked in the past. In the first instance, the behavioural side (motorists' responses) of congestion pricing has not been paid much attention. In general, it is argued that individuals are aiming to maximise utility (or minimise travel time). However, there seems to be an increasing recognition that this assumption does not properly describe reality. Second, the impact of the compensation scheme—used to compensate drivers who are worse off under congestion pricing—on the behavioural responses should be analysed more carefully in future work. This scheme might partly reverse the behavioural responses induced. Third, the welfare-generating properties of simple schemes should be looked at in future work. Fourth, given the potential opposition, we conclude that a cordon system, in which the price is dependent on the time of the day, is currently the most attractive option for pursuing a kind of congestion pricing. A cordon system might increase the individual's awareness of the costs of mobility during congested periods and be the first step towards more sophisticated pricing systems.

1 Introduction

Congestion on the roads is a pressing problem for most metropolitan areas around the world. It causes transportation problems in traffic networks, and, in addition, the consequential delays negatively affect economic activities as a whole. Furthermore, congestion has adverse effects on the environment; one could think of pollution, noise annoyance, etc. Many measures or instruments have been suggested to resolve (part of) the congestion problem. In this paper we will analyse the feasibility of an economic instrument that has caused a great deal of controversy: congestion pricing. Although on theoretical grounds it can easily be shown that congestion pricing is the first-best solution for efficiently dealing with congestion, this instrument cannot yet boost much public and political support. In this paper, various aspects, problems, and consequences associated with implementing congestion pricing will be discussed by reviewing the relevant literature. Solutions provided by different researchers to enhance the acceptability of a congestion-pricing scheme will be compared, and conflicting viewpoints will be identified and brought together.

The paper is organised as follows. In section 2 the theoretical first-best concept of congestion pricing is discussed and then the applications of this feature in practice are questioned. In section 3 the recent literature on the positive and negative aspects of actually implementing a congestion-pricing scheme is summarised. In section 4 attention is focused on the behavioural issues that are often overlooked, but yet of crucial importance. In section 5 the methods of implementing congestion

[¶] Affiliated to the Tinbergen Institute, Keizersgracht 482, 1017 EG, Amsterdam.

pricing are addressed. A distinction will be made between the actual technology used to collect the money and the political way of introducing the scheme to the public. In section 6 the Dutch attempts to introduce a kind of congestion-pricing scheme are discussed, and finally, in section 7 the main arguments in the paper are summarised and recommendations are made for further research.

2 The theory: first best?

In this section, the theoretical first-best concept of congestion pricing will first be analysed. Then the main focus is on the applicability of the first-best theoretical feature in real-world situations. In section 2.1 the notion of transport externalities is introduced; in section 2.2 the first-best concept of congestion-pricing is presented; and in section 2.3 this concept, when applied in realistic situations, is analysed.

2.1 Transport externalities

Mobility in general, and car mobility in particular, gives rise to a large number of external effects, also called externalities. In general, an external effect can be defined as:⁽¹⁾

"An external effect exists when an actor's [the receptor's] utility (or profit) function contains a real variable whose actual value depends on the behaviour of another actor [the supplier], who does not take these effects of his behaviour into account in his decision making process" (Verhoef, 1994a, page 274).

Within the transport network, externalities follow from the nontraded mutual interactions between road users. Driving on a congested road not only leads to a relatively long travel time for the driver involved, but also increases the travel times for all other drivers on the same road.⁽²⁾ The latter (cost) effect is not taken into account in the driver's decisionmaking process, which causes the external effect. Besides the congestion externality, there are other externalities involved with road transport. One may in particular think of noise annoyance, visual intrusion, pollution, and, last but not least, accidents (Verhoef, 1994a). In particular, the safety externality is important, as it is (depending on the valuation of life; see Jones-Lee, 1990) in size often even larger than the congestion externality. Nevertheless most road-pricing efforts have been directed towards the congestion externality, particularly because this is the most tangible one; a large share of the population faces congestion on a daily basis.

To complicate matters further, interactions between the different types of external effects have also been mentioned in the literature. For instance, recently Shefer and Rietveld (1994) reported positive effects of congestion on safety. They claimed that in congested situations, fewer fatal accidents take place than in uncongested situations. US, German, and Japanese data on the distribution of fatal accidents over the hours of the day seemed to underline their theoretical model. The data revealed that the number of fatal accidents in the morning peak hours (although the most congested period of the day) is relatively low. On the other hand, environmental externalities (pollution) may generally be expected to increase with less smooth traffic flows. A final example is the interaction between noise and safety: a completely silent car may be expected to be very dangerous for other road users.

To facilitate the argumentation, we will be focusing mainly on the congestion externality; hence, in the remainder of the paper the term congestion pricing will be used to avoid confusion.⁽³⁾

⁽¹⁾ For a literature review on externalities, see Baumol and Oates (1988), and Mishan (1971).

⁽²⁾ Strictly speaking, the drivers behind the additional one are affected.

⁽³⁾ The term congestion pricing might not be the most appropriate one either. For instance, Sharp (1966) preferred congestion tax.

2.2 The first-best concept of congestion pricing

The theoretical concept of congestion pricing, stemming from Pigou (1920) and Knight (1924), and further explored by Walters (1961), Smeed (1964), and Sharp (1966), is based on levying a tax equal to the difference between the marginal social costs and marginal private costs (Pigouvian tax). In this way, the congestion externality is *internalised*⁽⁴⁾, implying that the negative effects on other road users, when joining a road, are accounted for in the user's decisionmaking process.⁽⁵⁾ In economic terms, the congestion price ensures that only economically efficient trips (in utility terms) are undertaken, and therefore, congestion pricing is viewed as the *first-best* instrument for tackling congestion.⁽⁶⁾

The assumptions needed to arrive at the first-best property are listed below.

- (a) Individual behaviour is rational, based on utility maximisation (cost minimisation).
- (b) There is full information on all costs involved (including detours) for both the road manager (or government) and the road users.
- (c) Time is a normal economic good, that is, it has a positive value.
- (d) Congestion pricing is applied to all relevant road segments in the network.
- (e) Congestion pricing is technically feasible and the transaction costs are reasonably low.

The assumptions about rationality and full information are generally made in economic theories. The third assumption is needed to ensure that congestion is associated with disutility. The fourth assumption is straightforward, and the fifth ensures that the welfare gains of applying congestion pricing are not outweighed by the costs of implementing the system. By applying congestion pricing, one can simply show that the net *social* benefits are maximised; the *dead-weight* welfare loss (given by the area of the triangle in the traditional diagrammatic analysis of congestion pricing) is avoided.

2.3 Objections to the first-best concept of congestion pricing

Several objections have been raised against the conventional (Pigouvian) concept of congestion pricing; in this section, these will be listed.

In the first instance, the analysis in the previous section is in nature a static one, whereas the real-world situation is obviously dynamic, especially with respect to congestion phenomena, even in the short run. A transportation system is highly dynamic, the traffic situation is changing continuously and is affected by random disturbances. Ran et al (1993) found that the static solution is not applicable (second best) to dynamic congestion-pricing problems. Furthermore, when we model congested transport networks in a realistic manner, solving for the correct congestion price leads to models that are mathematically untractable. Without simplifying assumptions, the models are difficult to solve (Boyce et al, 1990) and (if solvable)

⁽⁴⁾ Here, the term *internalisation* refers to Pigouvian taxation. Strictly speaking, however, Pigouvian taxation does not satisfy the definition of internalisation, as the *correct* (welfare maximising) Pigouvian tax is not internal to the economic process (Mishan, 1971; Verhoef, 1994b).

⁽⁵⁾ In the literature there has been some debate on whether the diagrammatical analysis of congestion pricing should be centred on the relationship between the cost of using a road and the *flow of traffic*, or on the cost of using the road and the *number of vehicles on it*. Nowadays, the consensus seems to be that the latter is the better representation, as the decision to use a road is essentially a decision to add to the number of vehicles on it (Else, 1981; see also Nash and Else, 1982 for some comments). Much of the debate between Evans and Hills [see Evans (1992) and Hills and Evans (1993)] concerns the same issue. Evans uses flow-based demand functions, whereas Hills rejects such an approach. As argued above, the theoretically more elegant and economically more sound approach is to consider the *number of trips*.

⁽⁶⁾ For a recent, detailed, and comprehensive analysis of congestion pricing, see Hau (1992) and Johansson and Mattsson (1995).

require much computational effort; simple analytical tools are not available (Ran et al, 1993). This is not a theoretical problem but a mathematical one. However, these practical problems become important the closer we get to the phase of implementation.

Second, and in relation to the previous point, it is important to understand whether the congestion price should be based on prevailing levels of congestion, or on predicted (future) levels of congestion. In the traditional, static theory this issue is irrelevant because, in such a framework, traffic flows do not evolve through time. However, in the real-world dynamic traffic situation this becomes an important issue. Below, we will argue that in a dynamic situation the theoretically correct congestion price should be based on the predicted levels of congestion. The argument can be best illustrated by figure 1 in which the driver's decisionmaking process and the role of congestion prices therein are depicted.

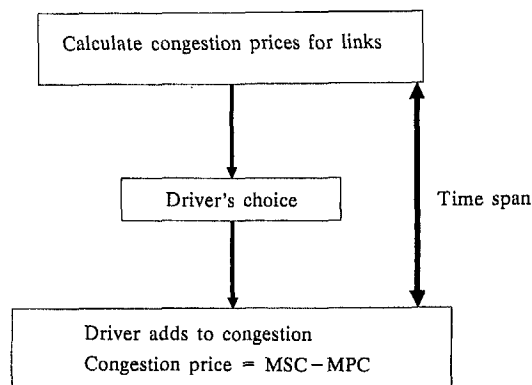


Figure 1. Congestion prices: based on prevailing or predicted levels of congestion? Note: MSC marginal social costs, MPC marginal private costs.

To induce the desired behavioural responses, the calculated congestion prices in the upper box of figure 1 should reflect the external costs caused by the driver in the lower box of figure 1. Therefore, the theoretically correct congestion price should not be based on prevailing levels of congestion, but on predicted levels of congestion, with a prediction horizon equal to the time span in figure 1. Moreover, if the calculated levels (upper box) are not equal to the experienced levels of congestion (lower box), for example, owing to a traffic accident, then the driver should still be charged for the calculated (predicted) price. The reason is that the driver's behaviour was influenced by the predicted charge and hence by the predicted level of congestion, not by the experienced level of congestion. Next, the question arises as to what extent we are able to predict future levels of congestion. Clearly, prediction of nonrecurrent traffic incidents is by definition impossible. However, Ishtiaq and Hounsell (1993) suggest that short-term forecasting of traffic congestion is feasible with reasonable accuracy.

Related to this point, we should inform the driver on the congestion price. Without this information, the driver will not be able to adjust his or her travel decision properly according to the prevailing travel costs. Hence, a congestion-pricing scheme and a motorist information system cannot be viewed as independent instruments for tackling the congestion problem, but instead have to be implemented simultaneously. An equilibrium model for so doing has recently been developed (Emmerink et al, 1995b; Verhoef et al, 1994a).

Third, to arrive at the first-best conclusion, all the prevailing externalities have to be taken care of in the road price. As stated in section 2.1, in this paper we will be mostly concerned with the congestion externality. Here, however, it is important to stress that the safety and pollution aspects should also be taken into account to tackle the problem in a first-best manner. Taking the congestion externality into account is a difficult task in itself, but it is even more complicated to account for pollution and safety as well. This is because: (1) not all pollutants correlate in a similar fashion with speed; (2) the economic value of pollution (that is, the many external environmental costs) cannot be calculated in any precise manner; (3) the correlation between the different externalities is not very clear either (for safety and speed, see Shefer and Rietveld, 1994). Hence, it might be questioned whether there is enough knowledge of the behaviour of the transport system to implement road pricing in a first-best manner.

Fourth, the conventional analysis assumes homogeneous traffic; an assumption that cannot be validated empirically. When we deal with heterogeneous drivers (in terms of vehicle type and value-of-time), the congestion price should be discriminatory. In theory this can be easily accomplished; in practice, however, taking this forward may be much harder. In this context, Evans (1992), and FitzRoy and Smith (1993) preferred road rationing through priority lanes to congestion pricing, in order to resolve (part of) the congestion problem.

Fifth, in the traditional analysis, an extremely simple network structure, without any traffic control components, is considered. In reality, one observes more complex networks and, as a consequence, the interaction between link flows and traffic control should be taken into account. This is (very) important, as traffic control plays a crucial role in directing traffic flows in large networks (Ghali and Smith, 1992; Smith and Ghali, 1992).

Sixth, Hills and Evans (1993) added that the complexity of travel behaviour (travel demand is a derived demand) is not accounted for in the conventional congestion-pricing analysis, and concluded that it is not feasible to model congestion and congestion pricing in a simple way. In particular, the assumption of rational behaviour based on cost minimisation might be questioned in practice. This is so important that section 4 will be devoted to clarifying these behavioural issues.

To conclude, although in a simplified theoretical framework congestion pricing is the first-best instrument for tackling the congestion externality, in practice this first-best character may be difficult to achieve. A congestion-pricing scheme is *first-best* only if all the first-best assumptions are satisfied; otherwise the scheme is *second-best*. In a second-best congestion-pricing scheme, the optimal (welfare-maximising) toll is not necessarily equal to the difference between marginal social costs and marginal private costs. Instead, the optimal second-best toll is generally some kind of weighted average of the costs caused by the relevant external effects (Verhoef et al, 1995). The arguments presented in this section suggest that the traditional congestion-pricing analysis (although appealingly simple) is not suitable for dealing with real-world situations. The still existing gap between theory and practice is considerable and deserves more attention. Viewed from this perspective, congestion pricing might be seen as just another second-best tool for resolving (part of) the congestion problem, although it may often be expected to approach first-best standards more closely than other second-best tools.

3 Congestion pricing: pros and cons

Having analysed the complexity of the theoretical concept of congestion pricing in section 2, we will, in this section, bring some practical evidence into the discussion.

In section 3.1 the practical advantages of congestion pricing are discussed, and in section 3.2 potential practical problems are presented.

3.1 Advantages of congestion pricing

Notwithstanding the objections to the simplified one-link homogeneous traffic context, congestion pricing remains the, so-called, first-best solution for tackling the congestion problem in this simple context. Other available instruments do not possess the potential of achieving the social welfare-maximising solution in such a simplified context (Verhoef et al, 1995). These instruments, often indicated as second-best tools, implicitly attempt to internalise the congestion externality by affecting mobility-related markets. A few examples of second-best instruments are: (1) parking charges; (2) public transport subsidies; (3) fuel taxation; (4) vehicle license fees (or vehicle quota systems⁽⁷⁾); (5) road rationing (special lanes for high-occupancy vehicles); (6) the use of telematics to improve network efficiency. (For a more exhaustive list of alternatives to congestion pricing and for useful references, see Button, 1992.)

Besides being a first-best instrument in the simplified context, congestion pricing has three additional attractive features.

- (a) Being a financial instrument, congestion pricing addresses the problem of latent demand directly by using money rather than delays to ration road capacity. This is in contrast to the more traditional solution of offering additional road capacity.
- (b) Congestion pricing provides the government with an opportunity to privatise (part of) the road network operations.
- (c) Congestion pricing raises the government's revenues by taxing externalities rather than economic productivity.

Most second-best instruments do not possess the first characteristic. Frequently, measures taken by the government to curb traffic flows are frustrated by the unexpected appearance of latent demand. One of the most interesting results of a study addressing the effects of the completion of the Amsterdam ringroad is the *return to the peak* phenomenon (Rijkswaterstaat, 1991). The study showed that a relatively large number of drivers who previously (before the completion of the ringroad) used the highway before 7 AM or after 9 AM moved to a more 'convenient' departure time within the 7–9 AM time interval. In fact, these latent demand effects are consequences of Downs's (1962) *fundamental law of peak-hour expressway congestion*, implying that capacity expansion does not affect peak-period travel speeds.

The second point, on the one hand, widens the scope of the government's policy options, whereas, on the other hand, the public may (and most likely will) be negatively affected by a privatised road network, particularly when the exploiting companies act as purely profit-maximising entities.⁽⁸⁾ In addition, owing to the market failures arising from the external effects in road transport, it is economically inefficient to rely on the *market* outcome. However, conversely one might expect that a private operator tends to be more efficient. Furthermore, private operators tend to be more willing to be innovative, to explore new technologies and techniques, which might be an advantage to the public (Gomez-Ibanez and Meyer, 1994). Therefore, privatisation of (part of) the network will create a tradeoff between efficiency gains on the one hand and welfare losses on the other. In addition, the overcharging by a monopolist could partly coincide with the value associated with

⁽⁷⁾ See Koh and Lee (1994) and Phang (1993) for recent assessments of the vehicle quota system in Singapore.

⁽⁸⁾ See Fielding and Klein (1993) for a recent paper on the franchising of highways.

the remaining externalities. Verhoef et al (1994b) analysed the situation where road users can choose between a tolled and an untolled route. They showed, *inter alia*, under which circumstances it is more efficient to privatise both routes, rather than to apply welfare-maximising congestion tolling to one of the two routes.

The third point mentioned above stresses the intrinsic good feature of congestion pricing. In contrast to most taxes, it does not penalise *economic productivity*; instead it penalises *economically inefficient use of scarce resources*, that is, it penalises use of scarce resources that are external to the economic process. This is widely viewed as a good principle for taxation (Atkinson and Stiglitz, 1980).

3.2 Disadvantages of congestion pricing

It is striking that most of the literature on congestion pricing is concerned with the disadvantages associated with the policy. From the beginning, congestion pricing has been perceived as a controversial method of curbing congestion, favoured by some experts but at the same time criticised by many opponents. Roughly speaking, most economists tend to support congestion pricing, whereas the public and politicians are opposed to congestion-pricing schemes:

“Although many transport and planning professionals are agreed that some form of road pricing is likely to be the most effective and flexible way of coping with the growth in urban traffic problems, it is clearly one of the least popular measures among the public at large” (Jones, 1991a, page 194).

The papers by Borins (1988), Evans (1992), Goodwin (1989), Jones (1991a), Oldridge (1990), and Seale (1993) provide a flavour of the divergence of opinions on the desirability, practicability, and usefulness of congestion pricing. In the following sections, the major objections to congestion pricing will be discussed, and methods to overcome these analysed. Altogether these arguments may be viewed as the main reasons for the public and political aversion towards congestion pricing.

3.2.1 Potential Pareto improvement

Although it is a first-best solution in the simplified framework, the implications of congestion pricing in practice are less clear. It is not without any reason that the political and public support to implement a congestion-pricing system is small (Jones 1991a). It is true that congestion pricing in the simplified context—as a first-best policy—maximises social welfare, but it is not true that this is accomplished by reaching a *strict* Pareto-efficient allocation, that is, all parties being better off. Instead it leads to a *potential* Pareto improvement, or, in other words, congestion pricing satisfies the Kaldor–Hicks welfare criterion (Hicks, 1939; Kaldor, 1939). In practice, however, the revenues obtained from congestion pricing may not be properly redistributed to make everyone better off. Without redistribution, most of the revenue obtained will accrue to the government. In this case both the *tolled* and the *toll-off* road users are worse off; the government is the winning party (Hau, 1992).⁽⁹⁾

In a recent paper, Lave (1994) contradicted this general consensus by arguing that, depending on the shape of the marginal net private-benefits curve, the aggregate consumer surplus may increase independently of how the revenues obtained are spent. His argument hinges on shifts in the value-of-time curve for different speeds. In Lave’s diagrammatical representation, different speeds are treated as different commodities. However, as pointed out by Verhoef (1994c), Lave does not allow for shifts in the relative position of drivers in the diagram that reflects the marginal benefits associated with a trip. Or, in other words, if driver A’s margin

⁽⁹⁾ To be precise, road users with a very high value-of-time will also be better off, and during periods of *hypercongestion* (density is beyond the corresponding point of maximum flow) everybody is better off (Hau, 1992).

benefits at 40 km h^{-1} exceed driver B's marginal benefits at that particular speed, then this is also the case for any other speed level. Verhoef challenges Lave on this assumption by arguing that this is not necessarily so.

3.2.2 *Redistributing the revenues*

The issue of redistributing the revenues is crucial for making congestion pricing a publicly acceptable instrument. Through a proper redistribution scheme, the potential Pareto improvement (Kaldor-Hicks welfare criterion) might be turned into a real Pareto improvement. The efforts made by both Goodwin (1989) and Jones (1991a) point in this direction. Goodwin (1989) argued that political and public support can be raised by dividing the revenues from congestion pricing in such a manner that all parties involved have something to gain compared with the current situation. He proposed a simple rule (the *rule of three*) to do so. Jones (1991a) suggested that a package of measures be set up around the congestion-pricing instrument to gain public support. Evidence from recently conducted surveys (Jones, 1991b) seemed to suggest that public support is sensitive to such approaches. Nevertheless, it is unlikely that a proper Pareto improvement (all parties being better off) will be accomplished.

In a recent paper, however, Small (1992) argued that the money raised through a congestion-pricing scheme is sufficient to implement practically a strict Pareto improvement. Following Burtraw's (1991) principle of *linked compensation*, Small attempted to offset the losses of motorists by taking measures that directly alleviate the harm done through the congestion-pricing scheme. However, Evans (1992) showed that in many cases the net benefits of a congestion-pricing scheme may be small in practice, compared with the redistributive impacts, so that the full compensatory features of Small's technique may be questioned. In addition, May (1992, page 328) claimed that "it has to be accepted that any form of road pricing will introduce some inequities", when compared with the current situation (the status quo). Furthermore, Small did not address the implications of feedback mechanisms on the behavioural responses of motorists. Section 4.2 of this paper will be devoted to a further discussion of this phenomenon.

3.2.3 *Attitudes towards congestion pricing*

In contradiction with the arguments above, Giuliano (1992) argued that equity and distributional considerations are *not* particularly important in regard to public acceptance. She argued that current investment policies often have a similar adverse effect on equity as congestion pricing would have. Hence, she concluded that distributional considerations are not a primary concern of congestion-pricing opponents, but adds that "distributional equity may present an apparently legitimate basis for opposition that is actually motivated by other reasons" (page 349).

The attitudes of politicians to congestion pricing have recently been investigated by Seale (1993) for London. Seale's analysis led to some surprising results. For instance, there appeared to be a positive correlation between the knowledge on congestion pricing and the support for congestion pricing. More fundamentally, Seale discussed two kinds of problems: problems of *principle* and problems of *practicality*. It was found that the principle of giving up *freedom* by paying for something that was up to now free will cost support and votes, and that the problem of *rat running* appeared high on the list of practical problems. Rat running is the term that refers to the problem of motorists trying to avoid the congestion price by driving on unpriced roads. Generally, these roads are not built with the objective of carrying much traffic; too much traffic on these (often small) roads leads to problems regarding the environment, noise, pollution, and congestion. Politicians identified

the relationship between the congestion price and other taxes as an important issue. In order to broaden the support for congestion pricing, the public should not be allowed to view congestion pricing as *just another tax*.

Another problem associated with congestion pricing refers to the way in which it is *perceived* by different groups in society. Owing to the wide impact of congestion pricing, it is viewed by different interest groups as a means of achieving different ends (Giuliano, 1992). For instance, the government may perceive it as an instrument that increases social welfare, raises government revenues, and provides a possibility of privatising roads. Environmentalists may view it as a means of stimulating car-pooling and the use of public transport, and hence reducing pollution and the need for new roads. Business people may perceive the congestion price as funding resources for new highways and continued economic development. It is clear that the interests of the above groups do not necessarily converge. However, this problem is more of a practical (perceptual or psychological) than of a theoretical nature. In theory, a first-best congestion-pricing scheme would simultaneously (1) raise government revenues, (2) decrease levels of pollution, and (3) increase the accessibility of congested areas, thereby rendering all the abovementioned interest groups better off.

3.2.4 Additional negative impacts

In addition to the previously mentioned problems, there are six additional negative aspects related to implementing congestion pricing. First, the low-income groups will be hit hardest by implementing congestion pricing; it will cause inequity (see Evans, 1992). According to economic principles, their trips will be suppressed disproportionately, as a result of their normally lower values-of-time and higher value-of-money (Verhoef, 1994c). However, a trip of a low value-of-time does not necessarily imply a trip of low social value. Evans (1992) also argued that the welfare gain (equal to the area of the dead-weight loss triangle) might be relatively small compared with the income shifts (from the road users to the government) for most levels of congestion. He questioned the desirability of gaining a relatively small welfare increase at the expense of large shifts in the distribution of income.

Second, congestion pricing will hit certain regions harder than others. Given the congestion-pricing concept, people living in congested areas will have to pay a high price for mobility, whereas no congestion price is levied in low-density areas, thus stimulating regional inequality and raising political problems. Imagine telling a regular road user living in a congested region that he or she has to pay for using the roads, whereas road users in rural areas have to pay nothing at all. For these reasons, fiscally neutral policies are often advocated. The impact of congestion pricing on economic activity is also not totally clear. On the one hand, congestion pricing will improve the accessibility of congested areas and might therefore induce more economic growth in these regions. On the other hand, congestion pricing might induce a shift from economic activities to relatively uncongested regions.

Third, and related to the previous point, congestion pricing may (indirectly) alter land-use patterns. This is because congestion pricing will affect the productivity of certain sites. Therefore, the location behaviour of firms will be influenced: heavily congested areas may become less attractive compared with the less congested ones. In general, these indirect effects are not necessarily negative, but they are extremely difficult to predict. Therefore, the outcome of a congestion-pricing policy is uncertain and thus the parties involved (firms, urban authorities) may oppose congestion pricing. A study in the Netherlands by Hols (1992) suggested urbanisation trends caused by employees moving to dwellings closer to their work location in order to avoid congestion charges.

Fourth, congestion pricing might provide perverse incentives to governments to raise revenues at the expense of users (Evans, 1992). In the theory of congestion pricing, it is assumed that governments (as monopoly suppliers of roads) will not exploit their monopoly power. Unfortunately, there is no clear rationale underlying this assumption and it might be seriously questioned in practical application. Without making this assumption, governments may overcharge motorists and under-supply infrastructure to increase the amount of revenues raised. Of course, this argument could also be put forward against the application of an emissions tax and in fact against any form of taxation.

Fifth, the argument that congestion pricing may endanger the individual's privacy is often put forward. This argument is not always justifiable, particularly not when a kind of smart-card system is proposed to implement the congestion-pricing scheme. Furthermore, evidence from various countries (for example, Italy) has shown that technologies such as automatic debiting systems have gradually been accepted at a wider scale. However, it is clear that any congestion-pricing system should be accompanied by privacy-protecting legislation.

Sixth, the costs of implementing and maintaining a congestion-pricing system should not be underestimated. However, recent evidence indicates that, for high-density, highly congested regions, these may be relatively low. For instance, Small (1992) estimated that for the Los Angeles region the collection costs would be about 4.4% of total revenues.

3.2.5 Summary

The problems associated with introducing a congestion-pricing scheme, as discussed in this section, may be best summarised by Borins (1988). Given the evidence of the electronic congestion-pricing experiment in Hong Kong, Borins concluded that overcoming the political implementation problems is extremely hard. In his view, congestion pricing is an intrinsically unpopular policy; it will always be opposed from different angles. The source of the opposition towards the introduction of any congestion-pricing scheme may stem from the public misperceptions of who is causing the problem. Or, as Sheldon et al (1993) put it:

"... no-one appears willing to accept that they contribute to the problem: it is typically something that is caused by *someone else*" (page 141).

4 Behavioural responses towards congestion pricing

In this section we will shed light on the behavioural issues involved in modelling congestion pricing. In section 4.1 the appropriateness of utility-based modelling principles is assessed. In section 4.2 we turn to the indirect responses, and in section 4.3 we discuss the (limited) empirical evidence on behavioural responses.

4.1 Modelling behavioural responses

Modelling the behavioural responses of road users to congestion pricing is a difficult task. Simple utility or cost-based or benefit-based models can be developed to do so, but it is questionable whether they capture the real-world travel-choice situation. Two analytical-economic problems have to be faced here:

(1) the assumption of some kind of *rationality*; and (2) travel demand is a *derived* demand, that is, it usually does not have any value or utility by itself.

The first and second points are addressed in sections 4.1.1 and 4.1.2, respectively.

4.1.1 Assumption of rationality

The assumption of *rational* behaviour is often made in modelling human behaviour and was needed to arrive at the first-best feature of congestion pricing in section 2.2.

This assumption, stemming from microeconomic theory, has been an issue for debate for over thirty years (Abelson and Levy, 1985). To provide a flavour of the debate, Simon (1990) recently argued that we may never be able to develop quantitative laws that describe human behaviour. Gärling (1994) explored this argument for travel-choice modelling and suggested several psychological theories with more accurate assumptions. As travel decisions are made so frequently (repetitious choices), it seems particularly unlikely for an individual to make a rational decision each time. Habitual behaviour or inertia might play a more important role than utility maximisation.⁽¹⁰⁾ Recently Van Berkum and Van der Mede (1993) incorporated a habitual component in their model of drivers' behaviour under information provision. Other methodologies that leave some scope for adjusted behavioural notions are offered by the fuzzy logic and approximate reasoning approaches; for an application of these theories to route-choice behaviour, see Lotan and Koutsopoulos (1993). Furthermore, one may use plausible heuristics to model drivers' behaviour. The boundedly rational model used by Mahmassani and associates (for example, see Mahmassani and Herman, 1990) and Emmerink et al (1995a) is an example of an intuitively appealing model.

4.1.2 *Derived demand*

Demand for travel is the result of the need to engage in certain activities, for instance, school, work, shopping, leisure, etc. That is, travel demand is a *derived* demand. Furthermore, travel demand is a derived demand with respect to the spatial organisation of economic activities (Verhoef and Van den Bergh, 1994). The activity-based approach "emphasizes this need to consider travel within a broader context through the pattern or sequence of activities undertaken by individuals at various locations in space during a period of time" (Fischer, 1993, page 25). An analysis of the effects of congestion pricing on travel behaviour is a typical example of a situation for which the activity-based approach is most suited because congestion pricing might have a great impact on individuals' daily activity patterns. Under congestion pricing, individuals are stimulated to, for example, chain more activities together. These changes in activity patterns cannot be captured in the traditional four-step approach which ignores the derived demand characteristic of travel. Unfortunately, conducting an activity-based analysis in practice is a difficult task, because (1) operational tools are not (yet) available (opposed to, for instance, the case of the traditional four-step approach where such tools are available), and (2) the required high-quality detailed travel diary data are not available. For a discussion of the likely problems inherent in collecting this kind of high-quality data, see Axhausen and Alves (1994).

4.2 *Indirect responses*

The analysis of drivers' responses is further complicated by the indirect effects of introducing a congestion-pricing scheme. Most analyses of congestion pricing consider only the direct impacts of the scheme; the indirect effects are ignored. In a theoretical context, this might be justified owing to the equality between the revenues of optimal congestion pricing and the costs of the optimal level of infrastructure supply (Verhoef and Van den Bergh, 1994). However, when the revenues are not used for optimal infrastructure supply (as most likely will be the case in any practical context) it is crucial to consider the indirect effects of compensation schemes when assessing the usefulness of the redistribution scheme under consideration. We will clarify this point with a simple example.

⁽¹⁰⁾ In some circumstances, habitual behaviour may be captured within a utility-maximising framework.

Assume that we are dealing with a situation that can be described with the simple one-link, homogeneous traffic framework for congestion pricing. Further, assume that the government raises the proper congestion price (the difference between the marginal social and marginal private costs). Then, by measuring the changes in welfare, we can easily determine that society as a whole will benefit from the scheme; there is an increase in social welfare. However, if the government decides to reimburse the road users that are worse off with a part of the obtained revenues, the road users might (partly) reverse their changed behaviour. The road users might again account for their marginal private costs only, and, as a result, the congestion-pricing scheme will have no effect on traffic flows. Clearly this is an extreme case and a typical example of the so-called *buy-back* effect: the government fully compensates depending on the individual's behaviour. However, the current debate on how to make congestion pricing acceptable to the public and politicians is related to the use of certain reimbursing schemes, of which the indirect effects are not immediately clear but should be carefully investigated. Figure 2 shows a schematic representation of the above discussion.

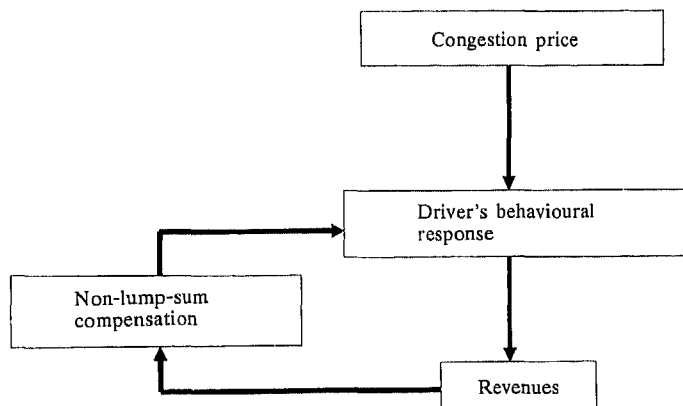


Figure 2. Compensation effects of congestion pricing.

In general, a change in the price of a commodity has two separate effects, the *substitution* effect and the *income* effect (see the Slutsky equation, Varian, 1992, page 120). If compensation is carried out according to the theoretical concept of *lump-sum* subsidies, then the buy-back effects, as mentioned above, will be very limited. By definition, the lump-sum redistribution scheme will not induce a substitution effect; the income effect remains. In theory, the income effect will shift the (derived) demand curve for trips outwards, and this would influence the optimal congestion price. In practice, however, the income effect can be expected to be a very small percentage of total income, and hence might be negligible. The theoretical concept of lump-sum compensation is difficult to implement in practice, because any compensation scheme will (either in the short or long run) induce certain behavioural responses. Therefore, the lump-sum concept should not be viewed as a realistic scheme, but rather as a theoretical construction that could serve as a benchmark for comparing schemes with the *ideal* situation. In practice, any scheme will induce behavioural changes, and, moreover, behaviourally oriented compensation schemes are more likely to be introduced to directly offset the *losers* of the congestion-pricing policy. Clearly, great care should be taken, as these schemes may suffer from the important drawbacks of the buy-back effects mentioned above.

In addition to the indirect compensation effect mentioned above, Fearon et al (1994) argue that congestion pricing might also have indirect effects on the price level of some goods. In their survey results they found that:

"... commercial-vehicle operators would continue to operate their vehicles during the priced periods and incur the road pricing costs. Any net costs, after congestion benefits have been taken into account, would generally be passed on to the customer. If such net costs occur, this would lead to a small increase in the cost of goods and services associated with the GV [goods vehicle] operations" (page 55).

Against the results of Fearon et al (1994) one might argue that companies might try to diminish their transportation costs by increasing the transportation activities during off-peak periods. Furthermore, Button (1978) argued that the *inflationary impact* will be fairly small because transportation costs form only a small part of total production costs. Finally, one might argue that the behavioural changes induced by implementing congestion pricing might (to some extent) be frustrated when the employer fully compensates the employee for the commuting costs.

To conclude, the analysis of these indirect effects is a difficult task, but as these effects may partly offset the direct ones, they should not be left aside in future work. As discussed in the previous section, the activity-based approach should play a more important role in dealing with these issues; the need for transportation is strongly linked with the engagement in and the chaining of activities.

4.3 Empirical evidence on behavioural adaptations to congestion pricing

In contrast to the vast amount of literature on the problems linked to implementing congestion pricing, the literature on the behavioural impacts of congestion pricing is rather limited. This might be because of the fact that worldwide only a few cities have adopted a certain kind of congestion pricing; here we would like to mention Singapore and Trondheim. Even for these sites, the charging structures are not so dependent on the level of congestion as they should be according to the theory; simple cordon schemes are used. Hence, practical evidence of (revealed) behavioural responses to congestion pricing is limited.⁽¹¹⁾

Another methodology for assessing the effects of congestion pricing on motorists' behaviour is the use of stated preference (SP) surveys.⁽¹²⁾ Although SP methods are getting more attention in the transportation literature, the technique has been sparsely used for investigating the impact of congestion pricing. Therefore, the remainder of this section is based on some preliminary findings.

The results of Meland and Polak (1993) for the Trondheim toll ring⁽¹³⁾ indicate a small shift from peak-period travel to travel during off-peak periods. Furthermore, they got different responses from different groups of people; it seems important to distinguish between commuters, business people, shoppers, etc. This may be an indication of the importance of different activity patterns for determining travel behaviour. However, the Trondheim results may not be indicative for other congestion-pricing schemes because the toll ring was particularly designed to raise money

⁽¹¹⁾ In Hong Kong, the technical feasibility of a sophisticated electronic road-pricing scheme has been shown (Catling and Harbord, 1985). However, owing to strong public opposition, the government was unable to implement the scheme (Borins, 1988).

⁽¹²⁾ See Polak and Jones (1995) for an overview of the issues involved in the use of SP methods in transport modelling.

⁽¹³⁾ A fixed amount is charged when crossing the boundary of the Trondheim toll ring. This is mostly done by automatic vehicle identification (AVI) and automatic debiting technology. Some 60% of the inhabitants of Trondheim live outside the ring. The ring operates Monday to Friday from 6am to 5pm; after 10am a discount is given to account for peak or off-peak

for new infrastructure: the main objective was not to price for externalities, and hence the charges were relatively low. Meland and Polak argued that the impacts on travel behaviour are also dependent on, for instance, flexible work arrangements, long shopping hours, etc. The impacts of congestion pricing should be analysed within the whole context, not in isolation.

Polak et al (1993) investigated how travellers might modify their time of travel under the influence of congestion-pricing charges which vary according to the time of day. They argued that, in order to tackle this issue, it is necessary to take into account the interrelationship between the timing of different journeys within an entire activity pattern. Polak et al (1993) used the concept of *time-of-day utility profiles* (see also Supernak, 1992) to analyse the effects of charging on the travellers' choice of time to travel. Although promising, their analysis is still in its preliminary stages. It is too early to draw any decisive conclusions.

Brown et al (1993) developed a set of demand elasticities for various congestion-pricing options in London. They argued that relatively little formal evidence exists of motorists' responses to an increase in the cost of travel as a result of the introduction of direct road-user charges. The demand elasticities that are assumed to be known in the literature (for example, demand elasticities with respect to fuel prices or public transport fares) cannot simply be transferred to a congestion-pricing context.⁽¹⁴⁾ In tables 5, 6, and 7, Brown et al (1993, page 175) provide estimates of elasticities (ranging from -0.03 to -0.8) under different congestion-pricing regimes. Again, it is important to note that these values differ greatly for different groups of people.

5 Implementing congestion pricing

In the previous sections attention has been paid to the theoretical concept of congestion pricing, the positive and negative aspects, and the behavioural responses that might be expected. In this section we will turn to a more practical question: the actual implementation of a congestion-pricing scheme. A modest attempt is made to answer the question of which congestion-pricing system is most likely to render the best results, given the current situation. To answer this question, a distinction should be made between:

- (1) the choice of charging system; and
- (2) the political way of introducing it.

The first and second points are discussed in sections 5.1 and 5.2, respectively.

5.1 Which kind of implementation?

Milne (1993) discusses the four road-user charging systems under consideration.

- (1) Toll cordons: a charge is levied at specific points in order to permit travel within a specified area, defined by a single boundary. The charge might be dependent on the time of day to account for congestion (for example, Trondheim).
- (2) Distance-based charging: the charge is based on the distance travelled in a certain area. In addition, the charge might be dependent on the time of day.
- (3) Time-based system: a charge is levied dependent on the time spent travelling in a specified area. Such a system has been proposed for Richmond in London. The charge may be varied depending on the time of day.
- (4) Congestion-metering system: charges are directly related to the prevailing level of congestion on the road network. The system proposed for Cambridge could be put into this category.

⁽¹⁴⁾ For recent papers on elasticities, see Goodwin (1992) and Oum et al (1992).

In table 1, factors that have an impact on the attractiveness of different types of congestion-pricing schemes are depicted. It is important to stress that the results in table 1 are exploratory in nature, and unfortunately not based on extensive scientific research. Given the lack of experience with real implementations of various types of congestion pricing, there is considerable uncertainty about their impacts. Therefore we only give a qualitative expression of the level of these impacts, and it is inevitable that these qualitative statements are to a certain extent subjective.⁽¹⁵⁾

Table 1. Assessment of the attractiveness of different types of congestion pricing.^a

Type	Costs (one-off)	Impact on congestion	User friendliness ^b	Side effects ^c	Implemen- tation ^d	Overall ^e
Cordon (F)	+	-	+	-	+	+
Cordon (T)	+	+	+	-	+	++
Distance-based (F)	-	-	+	-	-	-
Distance-based (T)	-	+	+	+	-	+
Time-based (F)	--	+	-	+	--	-
Time-based (T)	--	+	--	+	--	-
Congestion metering	--	+ ^f	--	+	--	-

Note: F fixed charges; T time-of-day dependent charges.

^a The impacts are measured at an ordinal scale ranging from most unfavourable (--) to most favourable (++) with - and + as intermediate outcomes.

^b Reflecting the predictability of the congestion price. This might have an important impact on the behavioural responses of the road users and the awareness of the costs of mobility during congested periods. In addition, it might positively affect public acceptance.

^c Reflecting shifts in land-use patterns. All these systems will induce certain shifts in land-use patterns, though these might be most undesirable under a cordon system.

^d Reflecting the difficulties associated with putting the theory into practice. For example, the problem of rat running falls into this category.

^e Overall assessment taking into account all relevant factors.

^f From a theoretical perspective, the impact on congestion of this implementation scheme is optimal. However, owing to the low predictability of the congestion price, the impact might be much lower in practice. (To properly inform the road users on the congestion prices, a driver information system is required; for example, see Verhoef et al, 1994a.)

Important factors affecting the attractiveness of different types of implementations are the costs of implementing the system, the impact on congestion, the predictability of the congestion price, the difficulties of implementing the technology, etc. Given the tentative results in table 1 and the risks associated with implementing the systems that have the greatest impact on congestion, the cordon system with time-dependent charges seems to be the most appealing policy option available.⁽¹⁶⁾

The importance of implementing a certain kind of congestion-pricing system is evident. However, it might be dangerous to proceed with technologically advanced systems. In a first phase, user awareness of the costs associated with mobility during congested periods should be realised. Then, in the second phase, there is a

⁽¹⁵⁾ The attractiveness of a particular scheme will also be dependent on other factors such as network structure, levels of congestion, etc. These are not taken into account in this paper.

⁽¹⁶⁾ In fact, a formal multicriteria analysis should be carried out to arrive at this conclusion. If in such an analysis a substantial weight (relative to the other factors) is given to the costs, the impact on congestion, and the user friendliness, then the cordon system with time-dependent charges will be the most attractive system.

fair chance that more advanced systems can be implemented successfully with the backing of the politicians and the public. If we bear in mind the quote by Sheldon et al (1993) (see section 3.2.5), that people perceive congestion as a problem caused by *someone else*, it seems that user awareness of the costs of congestion is not yet present. One of the main objectives of a simple time-dependent cordon system is to give shape to this user awareness.

Practical and survey evidence (Seale, 1993; Sheldon et al, 1993) also seems to suggest that politicians prefer a kind of cordon toll system. Such systems have already been implemented in Singapore, some Norwegian cities, and were proposed for the Netherlands (Stoelhorst and Zandbergen, 1990).⁽¹⁷⁾ Furthermore, Meland and Polak (1993) argued that a cordon system is relatively less risky compared with other proposed technologies.

The technology that will be chosen is also relevant for the applications that are available. For instance, Stoelhorst and Zandbergen (1990) mentioned Road Transport Informatics (RTI) systems as a possible application of the infrastructure provided by the congestion-pricing technology. The PAMELA project within the EU DRIVE I programme showed the feasibility of the technology to implement congestion pricing (Blythe and Hills, 1992), and these authors argued that it might also be suitable for RTI applications. At present, the PAMELA project is being taken further and the range of applications is being extended within the follow-up ADEPT project, which is part of the EU DRIVE II programme.

An important research question that needs to be considered is the percentage of welfare benefits that can be obtained with simple congestion-pricing systems. If, for instance, the time-dependent cordon system is able to give 80% of the potential welfare improvement (the potential welfare improvement is given by the area of the dead-weight loss triangle), then the marginal improvement of implementing a sophisticated system might be outweighed by the marginal costs of implementing such an expensive system. Hence, operationalisation of the theoretical concept of the *index of relative welfare improvement*, as described by Verhoef et al (1995), is highly relevant as a tool for trading off the costs and benefits of different kinds of congestion-pricing systems. A modest attempt in that direction has been made by Verhoef et al (1994a).

5.2 Method of introduction

Related to the political method of introducing, May (1992) discussed five models that can be used to introduce congestion pricing.

- (1) Policy-led approach: specify a broad policy of which congestion pricing forms a part, seek public approval, and then implement it.
- (2) Technology-led approach: develop complex technology to achieve congestion pricing.
- (3) Revenue-generating approach: specify the objective of raising money to pay for infrastructure from the start.
- (4) Make use of demonstration projects.
- (5) Analysis-led approach: a careful and objective assessment is made of the issues to be resolved, and an analytical programme designed to answer these.

The limited evidence in the literature seems to suggest that the revenue-generating approach is most suitable for gaining public support for congestion pricing. Following this approach, the government should clearly state the manner in which the revenues will be spent. Furthermore, as regards the public and political opposition,

⁽¹⁷⁾ See section 6 for a discussion of the Dutch proposal and the public responses.

a congestion-pricing system will be most successful if the redistribution scheme approaches a *strict* rather than a *potential* Pareto improvement (see section 3.2.2).

The fourth model mentioned above raises another important issue: which sites should be selected for introducing congestion pricing? Poole (1992) argued that "the least desirable place to start would be existing freeways, no matter how congested. Putting a price on something that has traditionally been offered free at the point of use risks major public and political resistance" (page 385). He claimed that the best sites for introducing the concept of congestion pricing are (1) existing toll facilities, and (2) completely new facilities which give users a choice compared with existing, unpriced facilities. Giuliano (1992) holds the same opinion and moreover adds that it is unlikely that congestion pricing will be implemented to any significant extent in the United States.

Grieco and Jones (1994) are more optimistic for Europe, however. They indicate that public support for congestion pricing will be strongest where current congestion is most intense. Given this localised character of congestion, they foresee an important role of municipalities—in addition to national governments—in introducing congestion pricing. A gradualist implementation strategy is called for in this case. Given the tendency that the public does not like high-tech charging and enforcement schemes, it may be better to start with low-tech solutions, according to Grieco and Jones. Furthermore, they observe that proposals to introduce congestion pricing in particular countries have led to a reinforcement of support for this policy in other European countries, even when these proposals were finally not accepted in the countries where they were originally formulated.

6 The Dutch failure to implement congestion pricing

In this section, the failure of the Dutch government to gain public support for the announced congestion-pricing scheme (the so-called 'Rekening Rijden' scheme) will be discussed. Long before a congestion-pricing scheme might have been implemented, the scheme was removed from the political agenda.

The facts about the system that was planned can be found in the Second Structure Plan (1988) of the Dutch government. On page 116, the objective, means, costs, and time period of the plan were described. The objective of the congestion-pricing scheme, as stated in the Second Structure Plan, was to decrease road traffic during the peak period. The means were by implementing a location-dependent and time-dependent electronic charging mechanism that influences the choices of departure time of car users and also the modal split in favour of public transport and the bicycle. The costs, dependent on the type of system to be implemented, were estimated at \$60 million. The system should have been operational in the years 1992–95. The objective of the scheme (as stated above) was not completely clear to everyone involved. Many people thought that the system was devised to be able to build a further five tunnels in the western part of the country. This, to some extent, clouded the real arguments.

The failure of the system was announced in May 1990 by the Minister of Transport, Public Works and Water Management in a letter to Parliament, less than two years after it was first mentioned by the government.⁽¹⁸⁾ In this letter the Minister wrote that she would refrain from any further steps leading to the introduction of this advanced congestion-pricing system. The reasons were rather vague: too much resistance from within society appeared to be the major one. In future,

⁽¹⁸⁾ Letter dated 7 May 1990 from the Minister of Transport, Public Works and Water Management to the Chairman of the Second Chamber of the States General, Tweede Kamer, 1989–1990, 20922, number 9.

the Minister said, she would turn to more traditional tools to achieve her objectives, rather than to such a sophisticated instrument. It is interesting to note that these less sophisticated systems—such as yearly peak travel passes and toll booths—have not been implemented thus far. Apparently, the *Rekening Rijden* experiment has put all these instruments in a bad light.

In a note that has not been made public, the government was more precise about the reasons for abandoning the advanced congestion-pricing system (see Visser, 1992). It was argued that: (1) the congestion-pricing scheme had to serve conflicting objectives simultaneously; (2) there was no political commitment to support the system; and (3) the great resistance from various parts within society was viewed to be a major obstacle. In section 3, these three points were also identified in our list of *cons* to congestion pricing. The public at large was not (yet) ready—or not (yet) prepared—to bear the consequences of such a radical, far-reaching change in the transport system. The introduction of a new market (a market for congestion) is clearly perceived as a large intrusion on the principle of freedom, paying for something that was up to now free of charge. The public awareness of the congestion problem was clearly not sufficient to generate enough support for this advanced policy.

In 't Veld (1991) adds another reason for the, in his view, 'logical failure of road pricing' in the Netherlands. In 't Veld argues that the

"... elegance and potential effectiveness of congestion-pricing as an allocation device have not contributed to its popularity. ... the elegance of congestion-pricing is at the same time a major threat. ... The possibility that congestion-pricing could register each illegal passage and send a bill or a fine or a combination of both afterwards, is a menace to all; perfection in the repression of illegality is not at all desirable to most citizens" (page 115).

In addition, he argues that fragmentation within society induces differentiated behaviour from individuals. The introduction of this congestion-pricing scheme clearly suffered from this fragmentation:

"Politics may for instance produce consensus or quasi-consensus into the direction of strong environmental policies on a very abstract level. As soon as the translation of these abstract policies into concrete measures is at stake, however, this consensus has disappeared altogether" (page 119).

In short, we can conclude that the introduction of a congestion-pricing scheme in the Netherlands failed because of the population's general attitude of dislike, and as a consequence of the lack of political commitment and political will to explain the need for such a system. The positive aspects of congestion pricing were given almost no attention in the debate on the desirability of the scheme.

The observations made in this section stress the importance of the need to increase the individual's awareness of the costs of mobility, particularly during congested periods, and to change the congestion-pricing debate from the negative aspects to the intrinsic positive side. To start with, a simple, time-dependent cordon-based charging mechanism might play an important role in changing the population's opinion towards greater understanding of these economical instruments.

7 Concluding comments

In this paper, the problems associated with the theoretical concept, the behavioural responses, and the implementation of congestion pricing were analysed with the arguments provided in the literature. Conflicting viewpoints were identified and brought together.

Although congestion pricing is a first-best instrument in theory, the assumptions needed to arrive at this conclusion oversimplify reality. In practice, congestion

pricing will most likely not be a first-best instrument for tackling the congestion externality, although it may be expected to be able to approach first-best standards more closely than any other instrument.

Congestion pricing has some important advantages over other available measures for curbing levels of congestion. Nevertheless, implementing congestion pricing will give rise to many problems: (1) it will lead only to a potential Pareto improvement; (2) it will cause horizontal inequity; (3) it might induce regional inequity; (4) it will provoke the question as to how to redistribute the revenues; (5) it may be perceived differently by different groups in society; (6) it might affect people's privacy; (7) it might be perceived as a loss of freedom; and (8) it may give rise to the problem of rat running.

The behavioural consequences of introducing congestion pricing have not been given much attention in the literature. Activity-based models and models that allow for a certain kind of irrational behaviour are most likely to be successful in predicting the responses of motorists under congestion pricing. Future research should shift into this direction rather than using the traditional four-step approach. Furthermore, the impact of the compensation scheme—used to offset drivers that are worse off under congestion pricing—on the behavioural responses should be given more attention, because the compensation scheme might partly offset the behavioural changes induced (buy-back effects).

There are different technological ways of introducing congestion pricing. If we take the potential opposition into account, a cordon system—in which the price is dependent on the time of day—seems currently to be the most attractive option. Such a simple scheme might increase drivers' awareness of the costs of mobility during congested periods. Moreover, a more sophisticated scheme can always be implemented once the simple system has proved successful and the awareness of the costs of mobility during congested periods have been established. The Dutch experience indicates that overcoming all the problems of introducing a relatively simple congestion-pricing scheme is already a cumbersome task.

Finally, future research should focus on the relative welfare improvement of simple congestion-pricing systems compared with more advanced ones. If simple systems are able to generate a large part of the welfare gains, then the need for implementing advanced systems declines.

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References

- Abelson R P, Levy A, 1985, "Decision making and decision theory", in *Handbook of Social Psychology, volume 1* Eds G Lindzey, E Aronson (Random House, New York) pp 231–309
- Atkinson T, Stiglitz J, 1980 *Lectures on Public Economics* (McGraw-Hill, New York)
- Axhausen K W, Alves M, 1994, "Taming travel diaries: some experiences with comparing travel diaries", Proceedings of the 26th UTSG Conference, 5–7 January, University of Leeds, Leeds; copy available from the author, the Leopold-Franzens-Universität, Innsbruck, Austria
- Baumol W J, Oates W E, 1988 *The Theory of Environmental Policy* 2nd edition (Cambridge University Press, Cambridge)
- Blythe P T, Hills P J, 1992, "Pricing and monitoring electronically of automobiles: the DRIVE project PAMELA" *Traffic Engineering and Control* 33 614–618
- Borins S F, 1988, "Electronic road pricing: an idea whose time may never come" *Transportation Research* 22A(1) 37–44

-
- Boyce D E, LeBlanc L J, Jansen G R M, 1990, "Design of a toll system for a congested intercity road network: the Dutch road pricing scheme", paper presented at the 37th North American Meeting of the Regional Science Association International, Boston, MA, 9-11 November 1990; copy available from the University of Illinois at Chicago, Chicago, IL
- Brown M B, Evans R C, Fox H, Mackie P J, Sheldon R, 1993, "The development of elasticities for a road pricing model", paper presented at 21st PTRC Summer Annual Meeting, Proceedings of Seminar F, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4, pages 159-175
- Burtraw D, 1991, "Compensating losers when cost-effective environmental policies are adopted" *Resources* **104** 1-5
- Button K J, 1978, "A note on the road pricing of commercial traffic" *Transportation Planning and Technology* **4** 175-178
- Button K J, 1992, "Alternatives to road pricing", paper presented at the OECD/ECMT/NFP/GVF Conference on The Use of Economic Instruments in Urban Travel Management, Basel, 18-19 June
- Catling I, Harbord B, 1985, "Electronic road pricing in Hong Kong: 2. The technology" *Traffic Engineering and Control* **26** 608-617
- Downs A, 1962, "The law of peak-hour expressway congestion" *Traffic Quarterly* **16** 393-409
- Else P K, 1981, "A reformulation of the theory of optimal congestion taxes" *Journal of Transport Economics and Policy* **15** 217-232
- Emmerink R H M, Axhausen K W, Nijkamp P, Rietveld P, 1995a, "Effects of information in road transport networks with recurrent congestion" *Transportation* **22**(1) 21-53
- Emmerink R H M, Verhoef E T, Nijkamp P, Rietveld P, 1995b, "Endogenising demand for information in road transport", Tinbergen Institute DP TI 95-38
- Evans A W, 1992, "Road congestion pricing: when is it a good policy?" *Journal of Transport Economics and Policy* **26** 213-243
- Fearon J, Scott M, Green M, 1994, "Commercial vehicle responses to congestion charging" *Traffic Engineering and Control* **35** 52-55
- Fielding G J, Klein D B, 1993, "How to franchise highways" *Journal of Transport Economics and Policy* **27** 113-130
- Fischer M M, 1993, "Travel demand", in *European Transport Economics* Eds J Polak, A Heertje (Basil Blackwell, Oxford) pp 6-32
- FitzRoy F, Smith I, 1993, "Priority over pricing: lessons from Zürich on the redundancy of road pricing" *Journal of Transport Economics and Policy* **27** 209-214
- Gärling T, 1994, "Behavioral assumptions overlooked in travel-choice modelling", Proceedings of the 7th international conference on travel behavior, Valle Nevado, Chile, 13-16 June; copy available from the author, the University of Göteborg, Göteborg, Sweden
- Ghali M O, Smith M J, 1992, "Road pricing: a new model for assessing the many options" *Traffic Engineering and Control* **33** 156-157
- Giuliano G, 1992, "An assessment of the political acceptability of congestion pricing" *Transportation* **19** 335-358
- Gomez-Ibanez J A, Meyer J R, 1994, "Private toll roads in the United States: recent experiences and prospects", paper presented at the ESCR Seminar on Transport and Urban Development, London, 18-19 April 1994; copy available from Harvard University, Cambridge, MA
- Goodwin P B, 1989, "The rule of three: a possible solution to the political problem of competing objectives for road pricing" *Traffic Engineering and Control* **30** 495-497
- Goodwin P B, 1992, "A review of new demand elasticities with special reference to short and long run effects of price changes" *Journal of Transport Economics and Policy* **26** 155-169
- Grieco M, Jones P M, 1994, "A change in the policy climate? Current European perspectives on road pricing" *Urban Studies* **31** 1517-1532
- Hau T D, 1992 *Economic Fundamentals of Road Pricing: A Diagrammatic Analysis* monograph, Transport Division, The World Bank
- Hicks J R, 1939, "The foundation of welfare economics" *The Economic Journal* **49** 696-712
- Hills P, Evans A W, 1993, "Road congestion pricing: a comment and a rejoinder" *Journal of Transport Economics and Policy* **27**(1) 91-105

-
- Hols M C A B, 1992, "Ruimtelijke effecten van rekening rijden", in *Stedelijke Ontwikkeling, Infrastructuur en Transport in de Randstad* Eds P Rietveld, E Kreutzberger (Delftse Universitaire Pers, Delft) pp 5-22
- In 't Veld R J, 1991, "Road pricing: a logical failure", in *Environmental Protection: Public or Private Choice* Eds D J Kraan, R J In 't Veld (Kluwer, Dordrecht) pp 111-121
- Ishtiaq S, Hounsell N, 1993, "Short term forecasting of traffic congestion in urban areas", paper presented at the 25th UTSG Conference, University of Southampton, Southampton, 6-8 January 1993; copy available from the author, the University of Southampton, Southampton, England
- Johansson B, Mattsson L-G, 1995 *Road Pricing: Theory, Empirical Assessment and Policy* (Kluwer Nijhoff, Boston, MD)
- Jones P M, 1991a, "Gaining public support for road pricing through a package approach" *Traffic Engineering and Control* **32** 194-196
- Jones P M, 1991b, "UK public attitudes to urban traffic problems and possible counter measures: a poll of polls" *Environment and Planning C: Government and Policy* **9** 245-256
- Jones-Lee M W, 1990, "The value of transport safety" *Oxford Review of Economic Policy* **6** 39-60
- Kaldor N, 1939, "Welfare propositions of economics and interpersonal comparisons of utility" *The Economic Journal* **49** 549-552
- Knight F H, 1924, "Some fallacies in the interpretation of social cost" *Quarterly Journal of Economics* **38** 582-606
- Koh W T H, Lee D K C, 1994, "The vehicle quota system in Singapore: an assessment" *Transportation Research* **28A**(1) 31-47
- Lave C, 1994, "The demand curve under road pricing and the problem of political feasibility" *Transportation Research* **28A**(2) 83-91
- Lotan T, Koutsopoulos H N, 1993, "Models for route choice behavior in the presence of information using concepts from fuzzy set theory and approximate reasoning" *Transportation* **20** 129-155
- Mahmassani H S, Herman R, 1990, "Interactive experiments for the study of tripmaker behaviour dynamics in congested commuting systems", in *Developments in Dynamic and Activity-based Approaches to Travel Analysis* Ed. P M Jones (Avebury, Aldershot, Hants) pp 272-298
- May A D, 1992, "Road pricing: an international perspective" *Transportation* **19** 313-333
- Meland S, Polak J W, 1993, "Impact of the Trondheim toll ring on travel behaviour: some preliminary findings", paper presented at 21st PTRC Summer Annual Meeting, Proceedings of Seminar F, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4, pages 103-115
- Milne D, 1993, "The network effects of alternative road user charging systems", paper presented at the 21st PTRC Summer Annual Meeting, Proceedings of Seminar F, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4, pages 91-102
- Mishan E J, 1971, "The postwar literature on externalities: an interpretative essay" *Journal of Economic Literature* **9**(1) 1-28
- Nash C A, Else P K, 1982, "Notes and comments: a reformulation of the theory of optimal congestion taxes" *Journal of Transport Economics and Policy* **16** 295-304
- Oldridge B, 1990, "Make yourself scarce" *New Civil Engineer* 1 March, pages 46-47
- Oum T H, Waters II W G, Yong J-S, 1992, "Concepts of price elasticities of transport demand and recent empirical estimates" *Journal of Transport Economics and Policy* **26** 139-154
- Phang S-Y, 1993, "Singapore's motor vehicle policy: review of recent changes and a suggested alternative" *Transportation Research* **27A** 329-336
- Pigou A C, 1920 *Wealth and Welfare* (Macmillan, London)
- Polak J W, Jones P M, 1995, "Using stated preference methods to examine traveller preferences and responses", forthcoming in *Understanding Travel Behaviour in an Era of Change* Eds M E H Lee-Gosselin, P R Stopher (Pergamon Press, New York)
- Polak J W, Jones P M, Vythoulkas P, Sheldon R, Wofinden D, 1993, "Travellers' choice of time of travel under road pricing", TSU Ref.766, paper presented at the 21st PTRC Summer Annual Meeting, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4

-
- Poole R W, 1992, "Introducing congestion pricing on a new toll road" *Transportation* **19** 383-396
- Ran B, Boyce D E, LeBlanc L J, 1993, "Dynamic congestion pricing models in an ATMS environment", paper presented at 40th North American Meeting of the Regional Science Association International, Houston, Texas; copy available from the Institute of Transportation Studies, University of California at Berkeley, Richmond, CA
- Rijkswaterstaat, 1991 *Ringweg Amsterdam: Effecten van de Openstelling Integraal Eindrapport* Rijkswaterstaat Dienst Verkeerskunde, Rotterdam, The Netherlands
- Seale K, 1993, "Attitudes of politicians in London to road pricing", PTRC 21st Summer Annual Meeting, Proceedings of Seminar F, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4, pages 117-128
- Second Structure Plan, 1988, Beheerste mobiliteit, bereikbaarheid, leefbaarheid, Part A: Beleidsvoornemen, Tweede Kamer, 1988-1989, 20922, 1-2
- Sharp C, 1966, "Congestion and welfare—an examination of the case for a congestion tax" *The Economic Journal* **76** 806-817
- Shefer D, Rietveld P, 1994, "Congestion and safety on highways: towards an analytical model", Tinbergen Institute DP TI 94-92, Amsterdam
- Sheldon R, Scott M, Jones P, 1993, "London congestion charging: exploratory social research among London residents", paper presented at the 21st PTRC Summer Annual Meeting, Proceedings of Seminar F, PTRC Education and Research Services Ltd, Glenthorne House, Hammersmith Grove, London W4, pages 129-145
- Simon H A, 1990, "Invariants of human behavior" *Annual Review of Psychology* **41** 1-19
- Small K A, 1992, "Using the revenues from congestion pricing" *Transportation* **19** 359-381
- Smeed R J, 1964, "The traffic problem in towns: a review of possible long term solutions" *Town Planning Review* **35** 133-158
- Smith M J, Ghali M O, 1992, "Two new models for assessing Urban Traffic Control and road pricing strategies" *Traffic Engineering and Control* **33** 245-249
- Stoelhorst H J, Zandbergen A J, 1990, "The development of a road pricing system in The Netherlands" *Traffic Engineering and Control* **31**(2) 66-71
- Supernak J, 1992, "Temporal utility profiles of activities and travel: uncertainty and decision making" *Transportation Research* **26B**(1) 61-76
- Van Berkum E C, Van der Mede P H J, 1993 *The Impact of Traffic Information* PhD thesis, Universiteitsdrukkerij, Delft, The Netherlands
- Varian H R, 1992 *Microeconomic Analysis* third edition (W W Norton, New York)
- Verhoef E T, 1994a, "External effects and social costs of road transport" *Transportation Research* **28A** 273-287
- Verhoef E T, 1994b, "Efficiency and equity in externalities" *Environment and Planning A* **26** 361-382
- Verhoef E T, 1994c, "The demand curve under road pricing and the problem of political feasibility: a comment", forthcoming in *Transportation Research A*
- Verhoef E T, Van den Bergh J C J M, 1994, "Sustainable transport: modelling interactions between transport, infrastructure, economy and environment in a spatial price equilibrium setting", Tinbergen Institute DP TI 94-63, Amsterdam
- Verhoef E T, Emmerink R H M, Nijkamp P, Rietveld P, 1994a, "Information provision, flat and fine congestion tolling and the efficiency of road usage", Tinbergen Institute DP TI 94-157
- Verhoef E T, Nijkamp P, Rietveld P, 1994b, "Second-best congestion pricing: the case of an untolled alternative", Tinbergen Institute DP TI 94-129; forthcoming in *Journal of Urban Economics*
- Verhoef E T, Nijkamp P, Rietveld P, 1995, "Second-best regulation of road transport externalities" *Journal of Transport Economics and Policy* **29** 147-167
- Visser J G S N, 1992, "Toltunnels in de randstad" *Infrastructuur, Transport en Logistiek* Volume 16 (Delftse Universitaire Pers, Delft)
- Walters A A, 1961, "The theory and measurement of private and social cost of highway congestion" *Econometrica* **29** 676-699